ECONOMIC SHOCKS, GOVERNANCE AND VIOLENCE

A SUBNATIONAL LEVEL ANALYSIS OF AFRICA

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ABSTRACT

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Economic shocks, governance and violence: A subnational level analysis of Africa

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Abstract By using a geo-coded disaggregated dataset in sub-Saharan Africa over the period 1997–2013, we exploit year-to-year rainfall variation as an instrumental variable to estimate the causal effect of economic shocks on civil conflict conditional on governance quality. We confirm earlier findings that adverse rainfall shocks increase the likelihood of conflict in sub-Saharan Africa. We also investigate the role of governance quality on conflict in sub-Saharan Africa. The results underscore that improvement of governance quality can effectively mitigate the detrimental effect of negative income shocks on regional peace. However, due to the limited penetration of countrywide governance structures, this effect of governance quality is more significant in areas closer from the capital cities than in the remote areas.

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1. Introduction

Violent conflict has been widespread in recent decades, particularly in developing countries. Economists document various major reasons for conflicts, such as religion, poverty, historical context, etc.[1] There has been a steady rise in the number of civil conflicts since the end of World War I. In any year over the last decade, 25-30 countries had an internal armed conflict. There is a large set of literature showing that economic growth and wealth level are negatively correlated with civil conflicts (Collier and Hoeffler, 2004, 1998, Fearon and Laitin, 2003). However, the identification strategies may cause biased estimates due to reverse causality or ommited social and political environment.

The cornerstone research by Miguel *et al*. (2004), henceforth MSS, documented the causal effect of adverse income shocks on civil conflict in sub-Saharan Africa, using year-to-year rainfall variation as an instrument for economic growth. MSS (2004) show a strong relationship between economic growth and civil conflict: a negative growth shock of five percentage points increases the likelihood of civil conflict in the next year by nearly one half. Following MSS, a cumulative body of literature exploits exogenous shocks of rainfall and temperature as the

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[1] See Blattman and Miguel (2010) for an overview.

instrumental variables for income shocks to estimate the causal effect of economic shocks on conflict. We will discuss this literature in the next section. [2]

Nevertheless, this line of research ignores the significant heterogeneity across countries. Each country has its own background in economy, institution, resources, and so on. And there exists heterogeneity that should not be ignored even within a country. Accordingly, Miguel and Satyanath (2011) and Ciccone (2011) both recommend using more disaggregated data to uncover the relationship between economic shocks and conflict. Our paper contributes to the literature by using detailed geo-coded disaggregated data in sub-Saharan Africa. Our units of observation are cells of 1 degree of latitude × 1 degree of longitude, roughly 110 X 110 KM each cell. We employ the ACLED (Armed Conflict Location and Event Data) database that collects comprehensive real-time data on violence in Africa, including the specific dates and locations of conflicts, the types of event, the groups involved, fatalities, and changes in territorial control. And also, due to the limitation of economic statistics in African countries, we proxy economic condition in each cell by night light density (NLD) collected by United States Air Force Defense Meteorological Satellite Program (DMSP).[3] To intrument economic shocks, our analysis exploits historical record of rainfall data from Climate Research Unit (CRU) at the University of East Anglia. By using this geo-coded disaggregated data in sub-Saharan Africa, we estimate the conflict event in a cell as a function of economic shocks, and a set of geo-referenced covariates including population density, resource endowment, governance quality, and so on. Our analysis find robust evidence to support earlier findings that adverse rainfall shocks have a strong causal effect on the likelihood of conflict in sub-Saharan Africa.

Another major contribution of our paper to the literature is the investigation of the role of institution in regional conflicts in sub-Saharan Africa. Miguel*, et al*. (2004) show that the impact of growth shocks on conflict is not significantly different in richer, more democratic, or more ethnically diverse countries. However, the long-standing institutional view asserts that institutional structures, including efficient constraints on the executive, property rights protection, rule of law, are the fundamental for development and public welfare (Acemoglu *et al*., 2001, 2005, Besley and Burgess, 2002). Our analysis underscores that regions of sub-Saharan Africa

[2] Some studies conduct reduced form regression to estimate the effect of weather shocks on conflict (Burke *et al*., 2009, Ciccone, 2011, Harari and La Ferrara, 2012, Hsiang and Burke, 2014, Hsiang *et al*., 2013, Jia, 2014, O'Loughlin *et al*., 2012, Theisen, 2012).

[3] Henderson *et al*. (2012) have shown the strong power of night light density in measuring economic growth.

under better governance are less prone to violence upon economic shocks. Michalopoulos and Papaioannou (2014) examine the overall and heterogeneous effect of national institution in Africa, and uncover the limited penetration of countrywide institutional structures. Most African governments are unable to broadcast power in regions far from the capital cities. By splitting the samples according to their relative distance to the capital cities, we also find the diminishing impact of countrywide governance in alleviating the effect of adverse income shocks on conflict in sub-Saharan Africa.

The remainder of this paper proceeds as follows. In section 2, we provide a brief overview of prior literature and demonstrate how our study departs from this literature. Section 3 documents our data sources and how we construct the measurements used in our estimation. In section 4 we discuss our identification strategy. Section 5 presents the econometric results. Section 6 concludes.

2. A brief overview of prior literature

Our study is related to two main strands of prior literature.

Since late 1990s, a group of researchers at the World Bank's "Economics of Civil War, Crime, and Violence" project, led by Paul Collier, have introduced econometric models into the field of conflicts and development. Their empirical works (Collier and Hoeffler, 2004, 1998, Fearon and Laitin, 2003, Sambanis, 2004) have made great contributions to find the correlates of civil conflicts. It is now well established that the occurrence of conflicts is robustly related with the economic conditions, ethnicity, population, natural resources, state institution, trade, as well as rough terrain.[4] However, as Blattman and Miguel (2010) argue: "In many cases it is still not clear which of the above correlates actually cause war and which are merely symptoms of deeper problems." The identification strategies in the earlier literature are not based on exogenous variation in the economic conditions, thus do not convincingly avoid endogeneity problem. The correlation might be misleading if it reflects reverse causality or ommited social and political environment.

Since sub-Saharan Africa is a less developed agrarian region of the world, where the economic growth heavily relies on the weather condition, the exogenous variation in rainfall is an ideal instrument for economics shocks. Miguel et al. (2004) make the first attempt to use

[4] See Blattman and Miguel (2010) for a more comprehensive overview.

rainfall growth as an instrument to document the causal effects of economic shocks on civil conflicts in Sub-Saharan Africa. After their influential work, many subsequent conflict-related empirical studies began to exploit rainfall variation to instrument income levels in rain-fed agricultural regions, while some others estimate reduced form relationship between climate variability and conflict. Burke*, et al*. (2009) and Couttenier and Soubeyran (2014) find the significant impact of weather on conflict in sub-Saharan countries. Similarly, Maystadt *et al*. (2013) document that droughts increased conflict in Somalia between 1997 and 2009. Adano *et al*. (2012) and Theisen (2012) find an effect of rainfall on conflict in Kenya. The evidence for the relationship between weather shocks and conflict has also been found in other regions out of Africa. For example, Bai and Kung (2011) find the relationship between Sino-Nomadic conflict and rainfall shocks in the history of China. Jia (2014) shows that suboptimal rainfall triggered peasant rebellions in China. Bohlken and Sergenti (2010) use rainfall volatility to predict Muslim– Hindu violence in India.

Another line of research exploits rainfall variation to establish causality between economic conditions and political outcomes. Burke and Leigh (2010) and Brückner and Ciccone (2011) apply rainfall fluctuation to uncover the effect of economic shocks on democratic changes in Africa. Dell *et al*. (2012) show that adverse weather shocks can increase the probability of irregular leader transitions (i.e., coups). Chaney (2013) combines rainfall and Nile river flood data to estimate the effect of economic shocks on political stability in Egypt.

Nevertheless, this strand of research that is made either in the cross-country level or country case study has inherent limitations. Since each country has its own characteristics in economy, institution, resources, and so on, subnational conflict factors and heterogeneity within country are ignored in the country-level analysis. On the one hand, the results from within country studies are difficult to be generalized. Therefore, Blattman and Miguel (2010) and Ciccone (2011) suggest using more detailed disaggregated data to improve our understanding of these open questions. Our study fills this gap by using disaggregated data in sub-Saharan Africa.

Harari and La Ferrara (2012) and Hodler and Raschky (2014) are a few exceptional studies investigating the relationship between rainfall shocks and conflicts using disaggregated data in Africa. However, Harari and La Ferrara (2012) only estimate the reduced form relationship between rainfall and conflict, without discussing how rainfall shocks impact on conflict. Hodler and Raschky (2014) lack control variables in their specification. Our analysis improves their estimation strategy, and explores the heterogeneous effect of rainfall shocks on conflict conditional on governance quality. We discuss the related literature on institution below.

Institutional quality is essential for public welfare, e.g., economic growth (Acemoglu*, et al*., 2001, 2005), health (Besley and Kudamatsu, 2006), reducing income inequality (Alesina and Rodrik, 1994), control of corruption (Ades and Di Tella, 1999), alleviation of famines (Besley and Burgess, 2002), etc. But the role of institution in mitigating the detrimental effect of income shocks on conflict has not been paid enough attention. Miguel*, et al*. (2004) find that the first-stage relationship between rainfall and growth is weaker after 2000. They suggest that it might be driven by the gradual progress of governance in African countries. A recent study by Burgess *et al*. (Forthcoming) examine ethnic favoritism in Africa. They find that districts that share the ethnicity of the president receive as twice as much expenditure on roads and have five times the length of paved roads built. However, ethnic favoritism disappeared with progress of democracy.

Nevertheless, Europeans' settlement in Africa was very limited to the coastline and the capital cities (Herbst, 2014). Consequently, colonial institutional structures, reflected through persistence on contemporary national institutions, have limited effect on areas far from the capital cities. The governments in Africa are usually very difficult to broadcast law enforcement and public policies to the remote areas, due to the lack of infrastructure and geographical obstacles, such as deserts, rugged terrains and rainforests. Michalopoulos and Papaioannou (2014) indicate that differences in countrywide governance structures in African countries cannot explain within-ethnicity differences in economic performance. Contrary to the overall effect, they find that national institutions do correlate with subnational development in the areas close to the capital cities within the same country.

Our study also sheds light on the limited penetration of national institutions, indicating the evidence for diminishing impact of countrywide governance in mitigating the effect of adverse income shocks on conflict in sub-Saharan Africa

3. Data and measurement

The starting point in constructing our dataset is to divide the South Saharan Africa (SSA) continent into equal-sized subnational cells: each cell is measured by 1 degree of latitude X 1 degree of longitude, or approximately 110 × 110 KM. Then, we collect geo-referenced data on civil conflict, rainfall, nighttime light density, as well as other information and assign them into each cell. Our sample consists of 1742 cells from 44 SSA countries over the period of 1997-2012.

Conflict

Data on civil conflicts, our dependent variable, is collected from the PRIO/Uppsala Armed Conflict Location and Event (ACLED) dataset. Regarded as the most comprehensive data that provides the location of each conflict event, ACLED dataset starts assembling relevant media reports since 1997 (Raleigh *et al*., 2010). ACLED records a range of civil conflicts, including battles, violence against civilians, remote violence, rioting and protesting, and even non-violent activity that is within the context of the war (rebels recruitment, for example). Following Harari and La Ferrara (2012), we denote a dummy conflict indicator as conflict_{it}. It is coded as one if at least one type of civil conflict event occurred in cell i in year t. Figure 1 Conflict (Battle) in 2000Figure 1, Figure 2 and Figure 3 map the three types of conflict respectively.

Economic shocks

The measures of economic development in the micro level in Africa are scarce. A cumulative set of empirical studies began to proxy GDP by nighttime luminosity. Henderson, *et al*. (2012) show that satellite image data on nighttime light density is a good proxy for GDP growth. They find night light density is strongly correlated with country-level GDP growth. Coming from the Defense Meteorological Satellite Program's Operational Linescan System (DMSP-OLS), satellite images report the luminosity for every 30 arc-second area pixel (approximately 0.86 square kilometers at the equator) every night at some instant between 20:30 and 22:00 local time. The National Oceanic and Atmospheric Administration (NOAA) process these raw images into final annual data on a scale from 0 to 63, with higher values implying greater night light density. The impacts of cloud cover, forest fires, and aurora or solar glare are removed after processing. Using night lights, we are able to analyze the economic shocks beyond the country level (see Figure 4 for an example). In addition, it allows us to address the problem of low-quality or unavailability of African regional GDP growth data. In case there is more than one satellite capturing the night light images, we take the average across satellites within cellyears. The variable NLG_{it} denotes the growth of night light density in cell i in year t and night light density in cell i in year $t-1$.

Rainfall

Another primary independent variable of interest is rainfall shock. Rainfall data is drawn from the Climate Research Unit (CRU) at the University of East Anglia, which provides monthly precipitation data on a 0.5 × 0.5 degree grid. We choose the period over 1960-2013 and transfer the original monthly data into 1 × 1 degree grid. Figure 5 maps the annual average rainfall over 1997-2012. Rainfall data before 1997 is used to generate the historical rainfall level for each cell. We denote R_{it} as the rainfall shocks in cell i between year t and $t-1$.

We construct four measures of rainfall shocks. This first measure is annual rainfall growth, calculated as $(\mathrm{rainfall}_t - \mathrm{rainfall}_{t-1})/\mathrm{rainfall}_{t-1}$. This measure in the most frequently used in the literature, such as Miguel, *et al*. (2004), Bohlken and Sergenti (2010) and Miguel and Satyanath (2011). The second measure, developed by Duflo and Pande (2007) in a study in India, is the fractional shock of rainfall in each cell, which is the deviation of rainfall from its average yearly level in historic record over period 1961–1995. The third measure is categorical shock of rainfall that has been used in the literature describing non-linear relationship between rainfall and agricultural output. For a given month, a categorical shock is defined to be positive one if the rainfall in this month is above the eightieth percentile and negative one if the rainfall in this month is below the twentieth percentile. Then the yearly categorical shock is the average over all months. For instance, Jayachandran (2006) and Kaur (2014) use this measure to estimate the relationship between rainfall and agricultural output. The fourth measure, namely absolute categorical shock, takes a different view that neither too much nor too little rainfall is blessing for agricultural production. For a given month, an absolute categorical shock is defined to be one if the rainfall in this month is either above the eightieth percentile or below the twentieth percentile. Then we again calculate the average over twelve months to obtain the yearly absolute categorical shock.

Governance quality

We use World Bank Governance Matters Indicators (WGI) as a proxy for governance quality. WGI data are measured in country level every year[5]. It reports on six broad dimensions of governance for 215 countries over the period 1996-2013, namely Voice and Accountability, Political Stability and Absence of Violence, Government Effectiveness, Regulatory Quality, Rule of Law, Control of Corruption. Each indicator is standardized ranging from -2.5 to +2.5 with higher values indicating a higher degree of governance quality. We sum up over the six measures to construct an indicator WGI as the countrywide governance quality. Since African governments are often lack of the ability to broadcast law enforcement and public policies to nationwide (Michalopoulos and Papaioannou, 2014), we want to examine the penetrative effect of governance in this context. So we split the samples into two groups according to their relative distances to the capital city within the same country. The distances are alculated using the Haversine formula.

Other controls

Following Collier and Hoeffler (2004) and Fearon and Laitin (2003), we include variables to control for regional characteristics of geography, demography, and natural resources. We use the measure of mountainous terrain (average elevation and its standard deviation in a cell), and distance to the seacoast to capture the geographic influence on conflicts. Mountainous terrain is assumed to increase risk of conflict since it increases the government's costs of controlling the territory. Data on mountainous terrain is coded from GTOPO30 global raster digital elevation model (DEM). And the distance to the seacoast calculate the geodesic distance to the nearest coastline from the centroid of each cell. Such data is drawn from Global Ministry Mapping System (GMMS), version 3.0. Population density for Africa in 2000 is employed to indicate the demographic characteristics. The United Nations Environment Programme / Global Resource Information Database (UNEP/GRID) surveys more than 109,000 administrative units in Africa and provides a 2.5 × 2.5 KM grid map. We also use four dummy variables to measure the existence of natural resources, which is assumed to increase the likelihood of civil conflicts. These dummies are whether a given cell has precious metals, industrial metals, oil or gems, respectively. Data for these dummies is drawn from the Mineral Resource Data System (MRDS)

[5] World Bank Governance Matters Indicators database provides annual data for each country except for the year of 1997, 1999, and 2001.

prepared by the United States Geological Survey (USGS). It is noticeable that the above control variables are cross sectional but time invariant. Figure 6 is the map indicating the locations of those natural resources.

Descriptive statistics are reported in Table 1.

4. Identification strategy

To address potential endogeneity problem, we propose to use exogenous rainfall variation as an instrument for night light density (*NLD*) growth in order to estimate the impact of economic growth on conflict.

The first stage relationship between rainfall variations and economic shocks is

$$NLG_{ict} = a + bR_{ict} + \gamma X_{ict} + \theta_c + \vartheta_{ct} + \varepsilon_{ict} \tag{1}$$

where NLG_{ict} is the annual growth rate of night light density in the cell; R_{ict} is the rainfall shock in the cell i in country c during the year t; X_{ict} is a vector of controls. θ_c indicates country fixed effect. ϑ_{ct} is country-specific yearly trend. R_{ict} takes various forms documented in the previous section. b is expected to be positive when R_{ict} is growth, fractional shock or categorical shock of rainfall, and negative when R_{ict} takes form of absolute categorical shock.

The second stage equation estimates the impact of income growth on conflict:

$$conflict_{ict} = \alpha + \beta NLG_{ic,t-1} + \gamma X_{ict} + \theta_c + \vartheta_{ct} + \varepsilon_{ict} \tag{1}$$

where $conflict_{ict}$ is binary variable of conflict incidence indicating whether the cell i in country c has experienced a conflict event recorded in the ACLED dataset during the year t. $NLG_{ic,t-1}$ is the lagged annual growth rate of night light density in the cell. We expect that $\beta < 0$. Since Logit and Probit may yield biased estimates when dealing with rare events (King and Zeng, 2001), our main estimation performs a linear probability model. We also conduct panel Probit and multilevel mixed effect estimation for robustness check, although the estimates are very similar.

Since the impact of economic shocks on conflict may also depend on whether the district is currently experiencing a conflict, we also examine how economic shocks affect the onset of conflict where onset is an indicator variable that captures conflict outbreak, i.e., $onset =$

$1(conflict_{it} = 1|conflict_{i,t-1} = 0)$. We conduct the estimation by using the same specification of equation (1) replacing outcome variable with conflict onset.

Our IV-2sls identification strategy relies on the assumption of exclusion restriction: rainfall shocks should affect conflict only through economic shocks. The correlation between governance quality (or governance quality improvement) and rainfall (or rainfall shock) is almost zero, ruling out the possible channel of governance through which rainfall variation can affect conflict. Another potential threat to our identification strategy is that extreme rainfall may make it difficult for both government and rebel forces to engage in violent conflict. In this case, our result may overestimate the effect of economic shocks on likelihood of conflict. The overestimation can be counteracted by the possibility that extreme rainfall may destroy the road network and thus undermine the role of government maintaining order and peace.

Although it is almost impossible to rule out all possible violations of exclusion restriction, we also perform the reduced form estimation procedure that provides unbiased estimate of effect of rainfall variations on conflict.

In order to investigate the role of governance in alleviating conflicts, the usual estimating equation is

$$conflict_{ict} = \alpha + \beta R_{ic,t-1} + \gamma_1 G_{c,t-1} + \gamma_2 R_{ic,t-1} G_{c,t-1} + \delta X_{ict} + \theta_c + \vartheta_{ct} + \varepsilon_{ict} \quad (2)$$

where $G_{c,t-1}$ is governance quality of country c in the previous year. γ_1 is the direct effect of the governance quality on conflict, whereas the interaction term is believed to capture the resilient effect of governance on rainfall shocks.

However, this estimation strategy is problematic. Suppose that $\gamma_2 > 0$ when rainfall variation takes form of growth, fractional variation or categorical variation, which implies that better governance has a mitigating effect on the impact of adverse rainfall shocks on conflict. However, it simultaneously implies a counterintuitive argument that with the same experience of positive rainfall shock a district with better governance is more likely to have conflicts than a district with bad governance. Similarly, $\gamma_2 < 0$ also suggests a contradiction. Therefore, a logically consistent estimation framework should be

$$conflict_{ict} = \alpha + \beta R_{ic,t-1} + \gamma_1 G_{c,t-1} + \gamma_2 R_{ic,t-1} G_{c,t-1} + \gamma_3 R_{ic,t-1} G_{c,t-1} * 1(R_{ic,t-1} > 0) + \delta X_{ict} + \theta_c + \vartheta_{ct} + \varepsilon_{ict} \quad (3)$$

While γ_2 capture the mitigating effect of governance quality on adverse rainfall shocks, $\gamma_2 + \gamma_3$ together indicate whether better governance structures are able to amplify the impact of positive rainfall shocks in reducing conflict. We hypothesize that $\gamma_2 > 0$ and $\gamma_3 < 0$ when rainfall variation takes form of growth, fractional variation or categorical variation. That is, better governance can reduce likelihood of conflict in both cases of negative and positive rainfall shocks. The absolute categorical shocks, without the possibility of being negative, are assumed to be negatively correlated with conflict. Therefore, equation (2) will be used to uncover whether better governance can resist the impact of adverse rainfall shocks on conflict. In the context of sub-Saharan Africa, γ_2 draws more attention.

Since we want to examine the penetrative effect of governance in this context, i.e., whether better countrywide governance is able to reduce the likelihood of conflict caused by rainfall shocks only within areas close to the capital cities, we divide the samples into two groups according to the relative distance of each cell to the capital in the same country and perform the same regressions as in equation (4). To derive each cell's relative distance within-country, we divide cell-to-capital distance by the maximum distance to the capital in each country.

An important issue in our econometric analysis is the method calculating standard errors. We display our main results by clustering standard errors at country level. When analyzing geo-referenced data with potential spatial interdependence, the prior development literature usually conducts OLS estimation with standard errors calculated by Conley (1999)'s method, which is robust to spatial dependence of unknown form in the error term. Therefore, we also conduct the regression by Conley (1999)'s method, following the procedure of Hsiang (2010) and adjusting standard errors for both spatial and intertemporal correlation.

5. Results

5.1 Rainfall, economic growth, and conflict

We start with the econometric results without considering the effect of governance. Table 2 contains the main results of the first stage of two-stage least square estimation, i.e., equation (1). Columns 1-8 repeat the analysis with various specifications that regress conflict incidence on four rainfall shock measures with or without adding control variables. All regressions find that rainfall shocks are significant determinants of economic shocks measured by night light growth.[6] Note that the reason for using categorical rainfall shocks is the possible non-linear relationship between rainfall and agricultural product, i.e., only adequately large variation of rainfall can affect agricultural output. Rather, the logic of using absolute categorical rainfall shocks is that too much or too little rainfall both have a detrimental effect on economic growth. Although Jayachandran (2006) and Kaur (2014) both find evidence supporting using categorical shocks in India, we doubt this specification in the context of African economy. The results in column 7 and 8 exhibit a much stronger relationship between absolute categorical rainfall shocks and economic shocks. We conduct Angrist and Pischke (2008)'s weak instrument multivariate F-test. Categorical rainfall shocks are relatively weak compared to other three instruments. It is probably because it is not correct to assume that extreme positive rainfall shocks are a blessing for agricultural production.

Table 3 reports the instrumental variable estimation of the effect of economic shocks on conflict incidence, i.e., equation (1). As shown in column 1, in absence of control variables in the regression, one percentage point increase in NLD growth lowers the likelihood of conflict incidence in the coming year by 0.467 percentage point. And this marginal effect remains significant and becomes even higher after we add control variables into the regression. Columns 3-4 and 7-8 also indicate that the likelihood of conflict incidence arises with negative economic shocks using fractional rainfall shocks and absolute categorical rainfall shocks as instruments. However, the effect becomes insignificant in columns 5-6 using categorical rainfall shocks as an instrument. The reason behind it is probably that categorical rainfall shocks are not a strong predictor for economic growth. Table 4 examines the reduced form relationship between rainfall shocks and conflict incidence.[7] A positive shock of rainfall growth or fractional variation can significantly lower the likelihood of conflict incidence. A higher level of absolute categorical rainfall shock causes conflict more likely to occur. Unsurprisingly, we do not find the effect of categorical rainfall shocks on conflict incidence in the reduce form regressions.

[6] To check the robustness, we also estimate standard errors accounting for spatial and serial correlation using Hsiang (2010)'s method. See Table 11.
[7] To check the robustness, we also estimate standard errors accounting for spatial correlation using Hsiang (2010)'s method. We report the results in Table 12.

Table 5 and Table 6 conduct the same regression analysis replacing conflict incidence with conflict onset.[8] We find that rainfall growth variations do not have a significantly enough effect to induce a new conflict. Rather, fractional and absolute rainfall shocks are strongly associated with conflict onset. Using them as instruments, columns 3-8 in Table 5 indicate that one percentage point increase in economic growth can lower the likelihood of conflict onset by 0.38-0.97 percentage point. Furthermore, comparing the effects of categorical rainfall shocks on conflict incidence and onset arises a question of theoretical and practical concern. Although categorical rainfall shocks may not be a reliable instrument for economic growth and thereby is not a strong predictor for conflict incidence, it is significantly associated with conflict onset. A spurious correlation between categorical rainfall shocks and conflict onset may exist, since categorical shocks and absolute categorical shocks may just coincide in predicting direction for conflict onset, even though categorical rainfall shocks are actually irrelevant with conflict incidence.

5.2 Governance, rainfall shocks, and conflict

Table 7 and Table 8 display the results of estimating equation (2) and (3) that investigate the role of governance in the relationship between rainfall shocks and conflict incidence along with conflict onset.[9] Table 7 shows that the variation in conflict incidence can be partly explained by governance quality. Higher governance quality is always linked with lower probability of conflict incidence. One point increase in WGI score can directly lower the likelihood of conflict incidence by about 0.05 percentage point. As shown in columns 2 and 4 that include two interactive terms, we find that higher governance quality can reduce the impact of adverse rainfall shocks on conflict incidence, and increase the impact of positive rainfall shocks on conflict incidence, $\gamma_2 > 0$and $\gamma_3 < 0$. That is to say, good governance, including government accountability and effectiveness and so on, can help maintain a peaceful environment where people suffer from the economic contraction caused by drought. And also, a better government can enlarge the delightful effect of good weather condition in lessening conflicts. However, we do not find such an effect in case of more extreme rainfall shocks (absolute categorical rainfall shocks). It is not quite surprising since the African countries

[8] See Table 13reporting the results using Hsiang (2010)'s method for standard errors estimation.
[9] We report the results estimating standard errors using Hsiang (2010)'s method in Table 14 and Table 15.

typically lack the good governance performance to adequately reduce the impact of extreme economic shocks on conflict.

Table 8 explores the role of governance in the relationship between rainfall shocks and conflict onset. We do not find a robust effect of governance quality across all specifications. Therefore, how governance affects the relationship between rainfall shocks and conflict outbreak awaits further investigation.

5.3 A discussion on the channel through which governance affects the relationship between rainfall and conflict

It is interesting to uncover the channel through which governance can affect the relationship between rainfall shocks and conflict. A plausible hypothesis is that a better government can directly improve the economic condition in areas affected by adverse rainfall shocks. Therefore, we regress NLD growth on rainfall shocks and WGI scores along with their interactive terms. The results displayed in Table 9 support this channel, i.e., better governance can amplify the impact of good weather condition and moderate the adverse effect of bad weather condition in economic activities.

5.4 Penetration of governance, rainfall, and conflicts

Finally, Table 10 displays the estimating results of equation (3) by splitting the samples into two groups according to their relative distances to the capital city within the same country. We use the mean distance to the capital across all cells within the same country as a cutoff, below or above which a cell is defined as a close or far cell. Conflicts are less frequent in areas with better countrywide governance. Regarding the governance effect on the relationship between rainfall shocks and conflicts, despite not being always significant, the magnitudes of coefficients of interaction terms always appear larger in magnitude in the close areas than the far areas, namely evidence for limited penetration of countrywide governance to the areas far from capital cities.

6. Concluding remarks

In this paper we conduct a geo-referenced disaggregated analysis of the empirical determinants of conflict in sub-Saharan Africa over the period 1997-2013. We construct a rich dataset of observations at the level of 1 degree of latitude × 1 degree of longitude, including economic performance proxyed by night light density, historical record of rainfall, conflict, as well as a set of controls. We exploit year-to-year variations in rainfall to instrument economic shocks. Our findings show robust evidence supporting prior literature that adverse rainfall shocks have a strong causal effect on the likelihood of conflict in sub-Saharan Africa. We also employ state of the art spatial econometric approach to check the robustness of our results.

We further investigate the role of governance quality in regional conflicts in sub-Saharan Africa. The results indicate that regions of sub-Saharan Africa under better governance are less prone to violence upon weather shocks. Better governance can amplify the impact of good weather condition and moderate the adverse effect of bad weather condition in economic activities. But we do not exclude the other possible channels through which governments can lessen conflicts, such as political and ideological interventions.

By splitting the samples according to their relative distance to the capital cities, we also find the limited penetration of countrywide governance in alleviating the effect of adverse income shocks on conflict in sub-Saharan Africa.

This study also provides a number of insights on reliable methodology in the line of research on conflict. First, it cautions against using categorical rainfall shock as an instrument for economic shocks. Second, it provides a more consistent and reliable estimation framework to evaluate the role of governance quality in the context of conflict. The results of this research should be hopefully helpful for policymakers make more effective efforts to prevent political and social unrest in developing countries.

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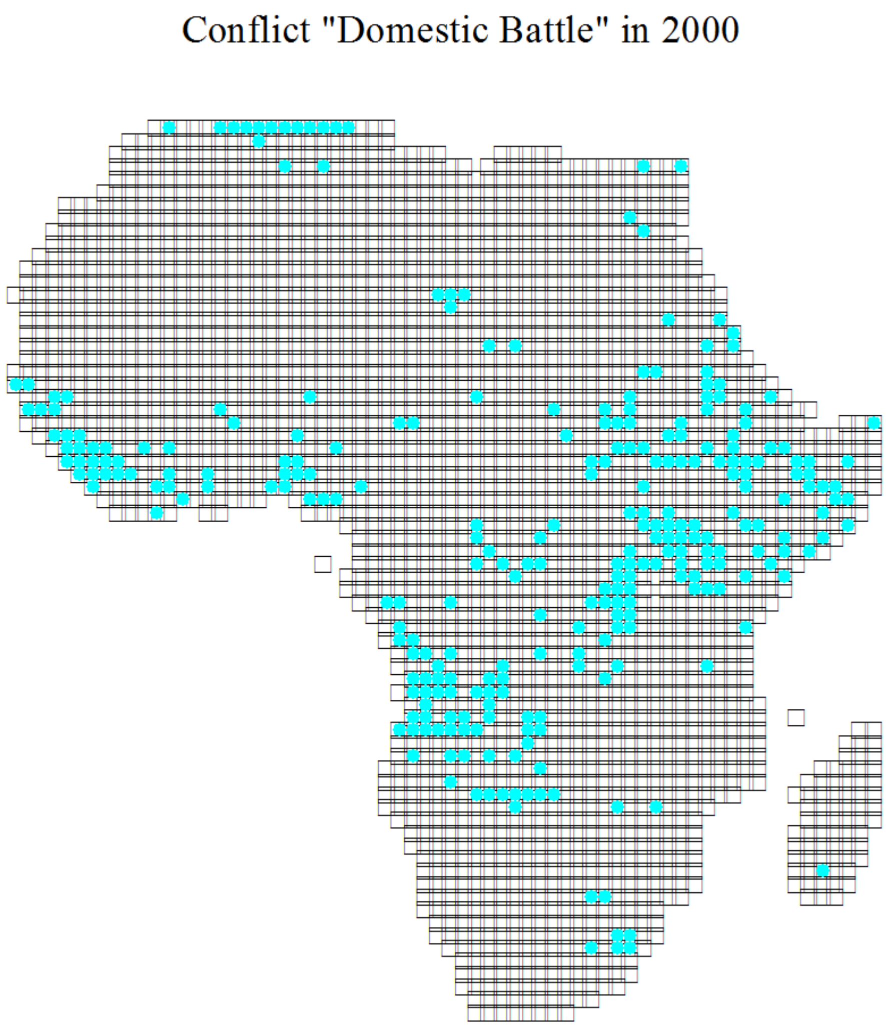

Figure 1 Conflict (Battle) in 2000

Figure 2 Conflict (non-Violence) in 2000

Figure 3 Conflict (violence) in 2000

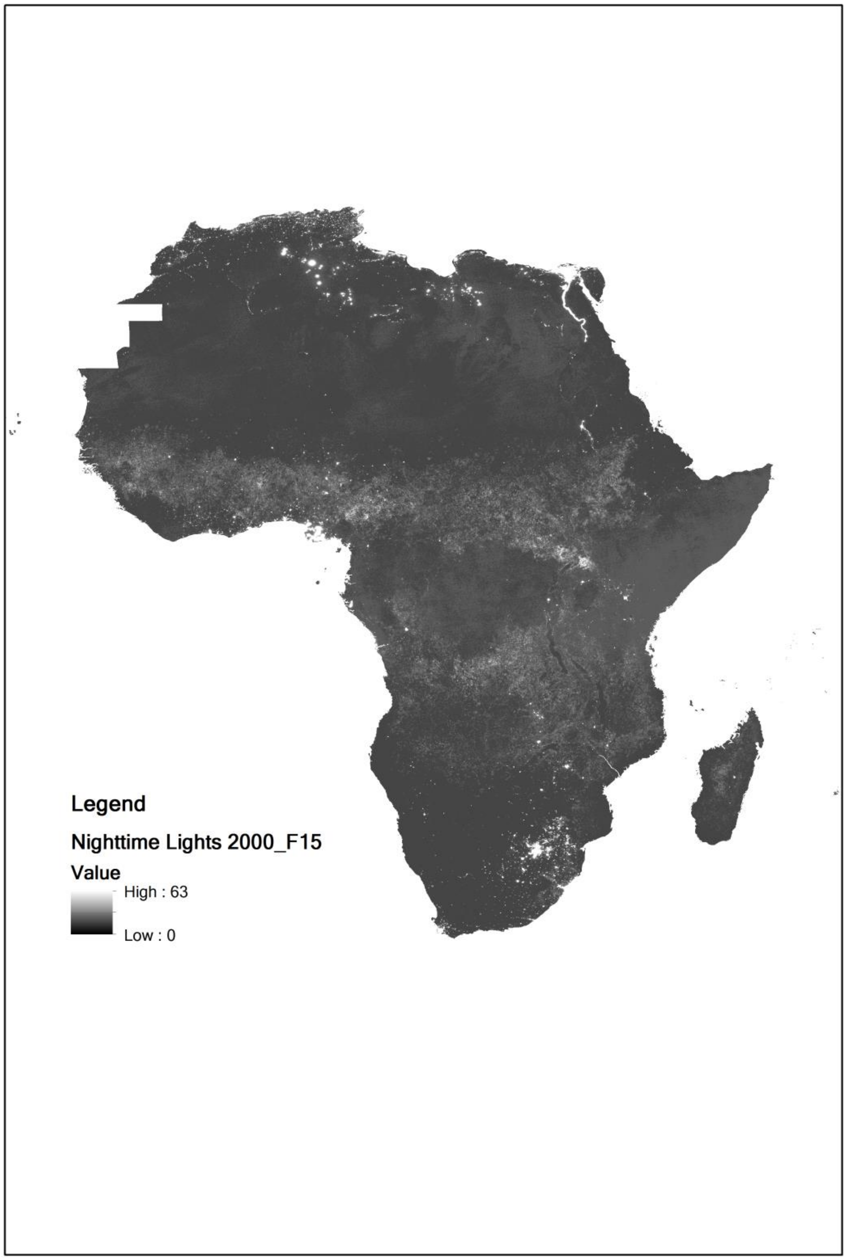

Figure 4 Night Light in 2000

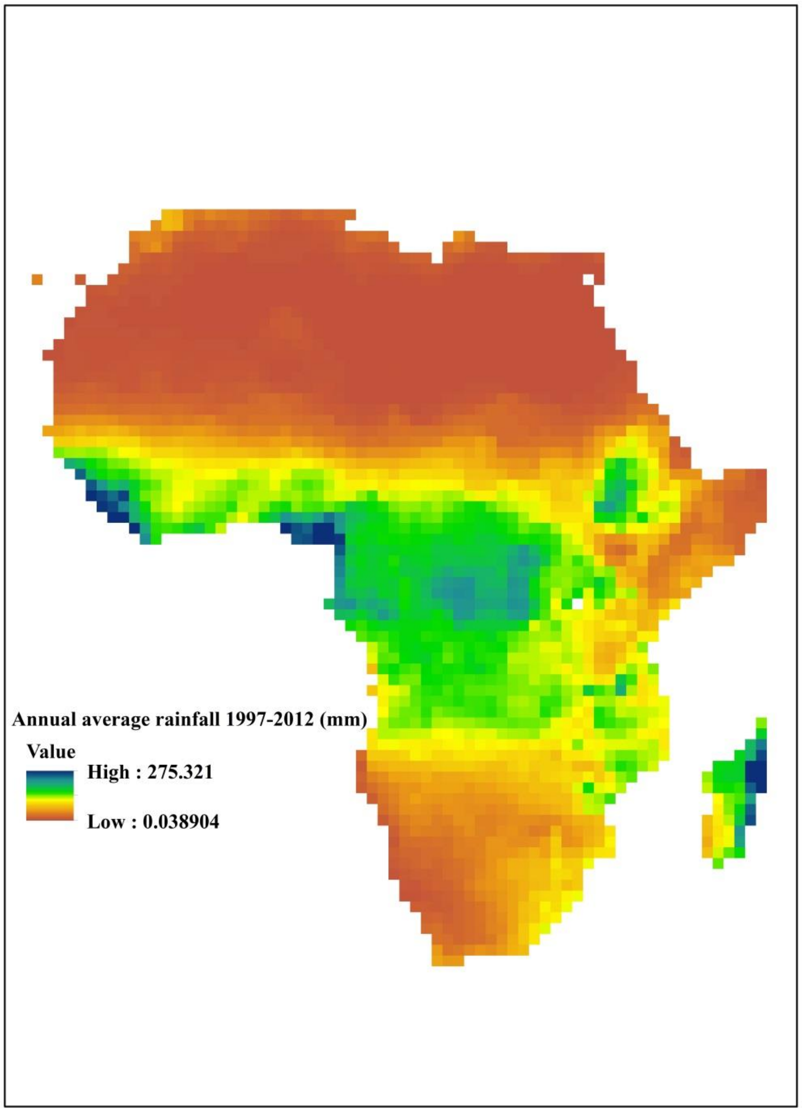

Figure 5 Annual average rainfall over 1997-2012

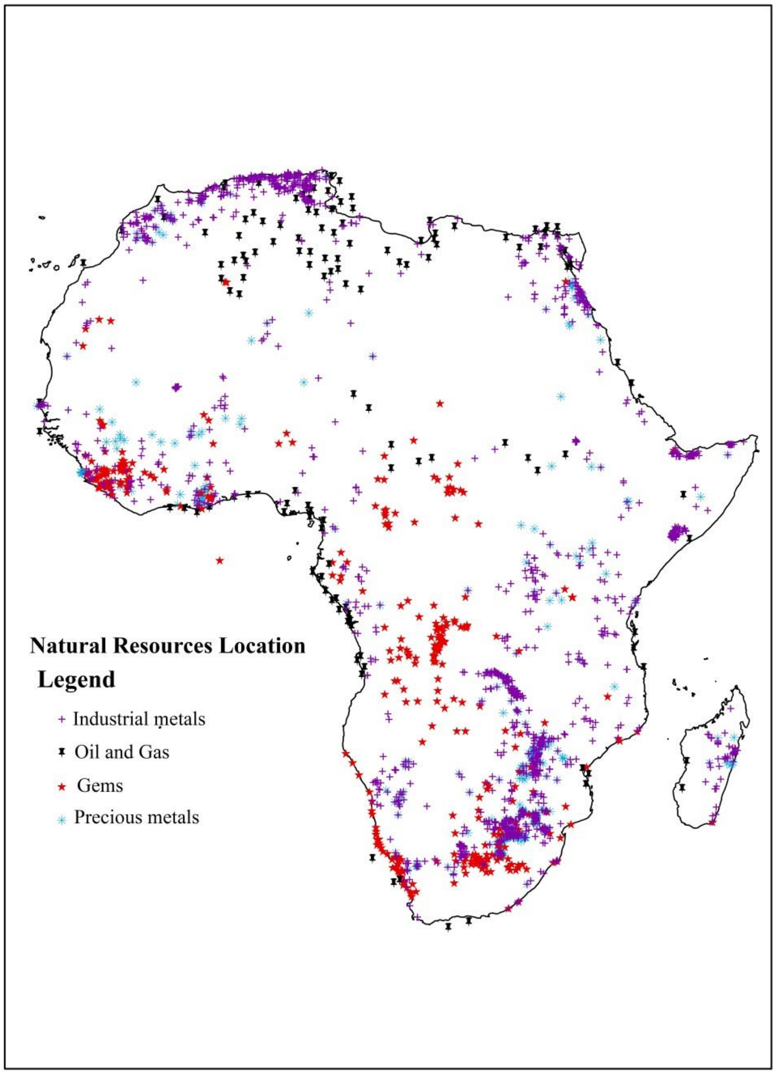

Figure 6 Natural Resource Map

Table 1 Descriptive Statistics

	count	mean	sd	min	max
Battle event	29614	0.132	0.339	0.000	1.000
Non-violent event	29614	0.122	0.327	0.000	1.000
Violent event	29614	0.146	0.353	0.000	1.000
Night light density	27872	3.209	2.051	1.000	63.000
annual rainfall	33083	945.734	583.119	0.000	5596.880
Governance (WGI)	26130	-4.966	4.385	-14.946	5.206
Polity2	33019	1.735	4.670	-9.000	9.000
Precious Metal	33098	0.072	0.259	0.000	1.000
Industrial Metal	33098	0.196	0.397	0.000	1.000
Oil Gas	33098	0.029	0.167	0.000	1.000
Germs	33098	0.111	0.314	0.000	1.000
Population Density	33098	637.279	1777.026	0.000	29696.000
Distance to Coast	33098	562.662	401.090	0.155	1585.482
Average Elevation	33098	695.863	460.981	-90.824	2468.176

Table 2 The First Stage Estimation

	(1) NLD growth	(2) NLD growth	(3) NLD growth	(4) NLD growth	(5) NLD growth	(6) NLD growth	(7) NLD growth	(8) NLD growth
rainfall growth	0.003***	0.003***						
	(0.000)	(0.000)						
fractional shock			0.005***	0.005***				
			(0.001)	(0.001)				
categorical shock					0.032**	0.032**		
					(0.015)	(0.015)		
abs. categorical shock							-0.150***	-0.150***
							(0.015)	(0.015)
F-stat	346.97	345.65	10.67	10.76	4.50	4.48	98.79	98.17
(p-value)	(0.00)	(0.00)	(0.00)	(0.00)	(0.04)	(0.04)	(0.00)	(0.00)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country specific trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
adj.R-squared	0.038	0.038	0.041	0.040	0.039	0.039	0.049	0.048
Observations	26118	26118	26120	26120	26130	26130	26130	26130

Notes: Standard errors are reported in parentheses and are clustered by country. * p<0.1, ** p<0.05, *** p<0.01.

Table 3 Instrument Variable Estimation (Incidence)

	(1) Conflict	(2) Conflict	(3) Conflict	(4) Conflict	(5) Conflict	(6) Conflict	(7) Conflict	(8) Conflict
NLD Growth	-0.467*	-0.634**	-0.732**	-0.642**	-0.732	-0.686	-0.718***	-0.824***
	(0.255)	(0.267)	(0.308)	(0.281)	(0.700)	(0.636)	(0.177)	(0.179)
IV	growth	growth	fractional shock	fractional shock	categorical shock	categorical shock	abs.categorical shock	abs.categorical shock
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country specific trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
adj.R-squared	0.096	0.066	-0.020	0.063	-0.019	0.042	-0.012	-0.035
Observations	26118	26118	26120	26120	26130	26130	26130	26130

Notes: Standard errors are reported in parentheses and are clustered by country. * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Table 4 Reduced Form Estimation (Incidence)

	(1) Conflict	(2) Conflict	(3) Conflict	(4) Conflict	(5) Conflict	(6) Conflict	(7) Conflict	(8) Conflict
rainfall growth	-0.001*	-0.002**						
	(0.001)	(0.001)						
fractional shock			-0.003**	-0.003**				
			(0.001)	(0.001)				
categorical shock					-0.023	-0.022		
					(0.027)	(0.025)		
abs. categorical shock							0.107***	0.123***
							(0.026)	(0.026)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country specific trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
adj.R-squared	0.175	0.213	0.176	0.213	0.176	0.213	0.178	0.215
Observations	26118	26118	26120	26120	26130	26130	26130	26130

Notes: Standard errors are reported in parentheses and are clustered by country. * p<0.1, ** p<0.05, *** p<0.01.

Table 5 Instrument Variable Estimation (Onset)

	(1) onset	(2) onset	(3) onset	(4) onset	(5) onset	(6) onset	(7) onset	(8) onset
NLD Growth	-0.293	-0.349	-0.519***	-0.506***	-0.968**	-0.965**	-0.367***	-0.382***
	(0.253)	(0.254)	(0.197)	(0.195)	(0.385)	(0.377)	(0.079)	(0.079)
IV	growth	growth	fractional shock	fractional shock	categorical shock	categorical shock	abs.categorical shock	abs.categorical shock
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country specific trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
adj.R-squared	-0.043	-0.067	-0.182	-0.168	-0.691	-0.683	-0.080	-0.085
Observations	26118	26118	26120	26120	26130	26130	26130	26130

Notes: Standard errors are reported in parentheses and are clustered by country. * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Table 6 Reduced Form Estimation (Onset)

	(1) onset	(2) onset	(3) onset	(4) onset	(5) onset	(6) onset	(7) onset	(8) onset
rainfall growth	-0.001	-0.001						
	(0.001)	(0.001)						
fractional shock			-0.002**	-0.002*				
			(0.001)	(0.001)				
categorical shock					-0.031**	-0.031**		
					(0.014)	(0.014)		
abs. categorical shock							0.055***	0.057***
							(0.013)	(0.012)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country specific trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
adj.R-squared	0.022	0.024	0.022	0.025	0.022	0.025	0.023	0.026
Observations	26118	26118	26120	26120	26130	26130	26130	26130

Notes: Standard errors are reported in parentheses and are clustered by country. * p<0.1, ** p<0.05, *** p<0.01.

Table 7 Governance, Rainfall Shock, and Conflict Incidence

	(1) Conflict	(2) Conflict	(3) Conflict	(4) Conflict	(5) Conflict	(6) Conflict	(7) Conflict
rainfall growth	-0.006**	-0.007**					
	(0.003)	(0.003)					
fractional shock			-0.002	-0.001			
			(0.002)	(0.002)			
categorical shock					-0.019	-0.019	
					(0.018)	(0.017)	
abs. categorical shock							0.105***
							(0.038)
WGI	-0.053***	-0.052***	-0.052***	-0.049***	-0.053***	-0.052***	-0.050***
	(0.018)	(0.018)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
WGI*rainfall growth	-0.002**	0.544*					
	(0.001)	(0.272)					
WGI*positive rainfall growth		-0.546*					
		(0.272)					
WGI* fractional shock			0.000	0.001***			
			(0.000)	(0.000)			
WGI*positive fractional shock				-0.003***			
				(0.001)			
WGI*categorical shock					-0.001	0.004	
					(0.006)	(0.006)	
WGI*positive categorical shock						-0.012	
						(0.008)	
WGI* abs.categorical shock							-0.003
							(0.005)
adj.R-squared	0.215	0.215	0.215	0.217	0.215	0.215	0.217
Observations	24376	24376	24378	24378	24388	24388	24388

Notes: All regressions include control variables, country fixed effects, and country specific trend. Standard errors are reported in parentheses and are clustered by country. * p<0.1, ** p<0.05, *** p<0.01.

Table 8 Governance, Rainfall Shock, and Conflict Onset

	(1) Conflict	(2) Conflict	(3) Conflict	(4) Conflict	(5) Conflict	(6) Conflict	(7) Conflict
rainfall growth	0.001	0.001					
	(0.003)	(0.003)					
fractional shock			-0.001	-0.001			
			(0.002)	(0.002)			
categorical shock					-0.017	-0.017	
					(0.013)	(0.013)	
abs. categorical shock							0.060***
							(0.022)
WGI	-0.017	-0.016	-0.016	-0.014	-0.016	-0.015	-0.015
	(0.015)	(0.014)	(0.014)	(0.013)	(0.014)	(0.014)	(0.014)
WGI*rainfall growth	0.001	0.458					
	(0.001)	(0.307)					
WGI*positive rainfall growth		-0.457					
		(0.307)					
WGI* fractional shock			0.000	0.001*			
			(0.000)	(0.000)			
WGI*positive fractional shock				-0.001***			
				(0.000)			
WGI*categorical shock					0.002	0.004	
					(0.004)	(0.004)	
WGI*positive categorical shock						-0.004	
						(0.004)	
WGI* abs.categorical shock							-0.001
							(0.003)
adj.R-squared	0.026	0.026	0.026	0.027	0.026	0.026	0.027
Observations	22634	22634	22636	22636	22646	22646	22646

Notes: All regressions include control variables, country fixed effects, and country specific trend.
Standard errors are reported in parentheses and are clustered by country. * p<0.1, ** p<0.05, *** p<0.01

Table 9 Economic shocks, rainfall shocks, and governance

	(1) NLD growth	(2) NLD growth	(3) NLD growth	(4) NLD growth
rainfall growth	0.005**	0.009***		
	(0.002)	(0.002)		
fractional shock			0.003	0.002
			(0.003)	(0.002)
WGI	-0.008	-0.013*	-0.011	-0.014**
	(0.007)	(0.007)	(0.007)	(0.007)
WGI*rainfall growth	0.001	-2.272***		
	(0.001)	(0.572)		
WGI*positive rainfall growth		2.275***		
		(0.572)		
WGI* fractional shock			-0.000	-0.002***
			(0.000)	(0.000)
WGI*positive fractional shock				0.003***
				(0.000)
adj.R-squared	0.048	0.057	0.051	0.058
Observations	22634	22634	22636	22636

Notes: All regressions include control variables, country fixed effects, and country specific trend. Standard errors are reported in parentheses and are clustered by country. * p<0.1, ** p<0.05, *** p<0.01

Table 10 Penetration of Governance, Rainfall Shock, and Conflict Incidence

	(1) Conflict	(2) Conflict	(3) Conflict	(4) Conflict	(5) Conflict	(6) Conflict	(7) Conflict	(8) Conflict
rainfall growth	-0.015	-0.008***						
	(0.044)	(0.001)						
fractional shock			-0.001	-0.001				
			(0.003)	(0.002)				
categorical shock					-0.027	0.001		
					(0.025)	(0.021)		
abs. categorical shock							0.078	0.107***
							(0.056)	(0.026)
WGI	-0.059***	-0.046**	-0.056***	-0.044**	-0.058***	-0.046**	-0.053***	-0.043**
	(0.017)	(0.020)	(0.016)	(0.019)	(0.017)	(0.019)	(0.016)	(0.019)
WGI*rainfall growth	0.868*	0.420*						
	(0.479)	(0.232)						
WGI*positive rainfall growth	-0.956*	-0.422*						
	(0.495)	(0.232)						
WGI* fractional shock			0.001**	0.001*				
			(0.001)	(0.000)				
WGI*positive fractional shock			-0.003***	-0.003***				
			(0.001)	(0.001)				
WGI*categorical shock					0.008	0.005		
					(0.008)	(0.006)		
WGI*positive categorical shock					-0.019*	-0.010		
					(0.010)	(0.008)		
WGI* abs.categorical shock							-0.013	-0.002
							(0.008)	(0.004)
distance to capital	Close	Far	Close	Far	Close	Far	Close	Far
adj.R-squared	0.249	0.225	0.251	0.227	0.249	0.225	0.252	0.227
Observations	11598	12778	11600	12778	11606	12782	11606	12782

Notes: All regressions include control variables, country fixed effects, and country specific trend.
Standard errors are reported in parentheses and are clustered by country. * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Table 11 The First Stage Estimation Using Hsiang (2010)'s GMM Method

	(1) NLD growth	(2) NLD growth	(3) NLD growth	(4) NLD growth
rainfall growth	0.003***			
	(0.000)			
fractional shock		0.005***		
		(0.001)		
categorical shock			0.032***	
			(0.010)	
abs. categorical shock				-0.150***
				(0.015)
adj.R-squared	0.072	0.074	0.072	0.082
Observations	26118	26120	26130	26130

Notes: Standard errors are computed by Hsiang (2010)'s GMM method and reported in parentheses. All regressions include control variables, country fixed effects, and country specific trend.
* p<0.1, ** p<0.05, *** p<0.01.

Table 12 Reduced Estimation (Incidence) Using Hsiang (2010)'s GMM Method

	(1) Conflict	(2) Conflict	(3) Conflict	(4) Conflict
rainfall growth	-0.002**			
	(0.001)			
fractional shock		-0.003***		
		(0.001)		
categorical shock			-0.016	
			(0.011)	
abs. categorical shock				0.106***
				(0.015)
adj.R-squared	0.403	0.405	0.403	0.405
Observations	29602	29604	29614	29614

Notes: Standard errors are computed by Hsiang (2010)'s GMM method and reported in parentheses. All regressions include control variables, country fixed effects, and country specific trend.
* p<0.1, ** p<0.05, *** p<0.01.

Table 13 Reduced Form Estimation (Onset) using Hsiang (2010)'s GMM Method

	(1)	(2)	(3)	(4)
	onset	onset	onset	onset
rainfall growth	-0.001			
	(0.001)			
fractional shock		-0.002***		
		(0.001)		
categorical shock			-0.032***	
			(0.008)	
abs. categorical shock				0.054***
				(0.011)
adj.R-squared	0.122	0.122	0.122	0.123
Observations	27860	27862	27872	27872

Notes: Standard errors are computed by Hsiang (2010)'s GMM method and reported in parentheses. All regressions include control variables, country fixed effects, and country specific trend.
* p<0.1, ** p<0.05, *** p<0.01.

Table 14 Governance, Rainfall Shock, and Conflict Incidence Using Hsiang (2010)'s GMM Method

	(1) Conflict	(2) Conflict	(3) Conflict	(4) Conflict	(5) Conflict	(6) Conflict	(7) Conflict
rainfall growth	-0.006**	-0.007**					
	(0.003)	(0.003)					
fractional shock			-0.002	-0.001			
			(0.002)	(0.002)			
categorical shock					-0.019	-0.019	
					(0.016)	(0.016)	
abs. categorical shock							0.105***
							(0.022)
WGI	-0.053***	-0.052***	-0.052***	-0.049***	-0.053***	-0.052***	-0.050***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)
WGI*rainfall growth	-0.002*	0.544**					
	(0.001)	(0.266)					
WGI*positive rainfall growth		-0.546**					
		(0.266)					
WGI* fractional shock			0.000	0.001***			
			(0.000)	(0.000)			
WGI*positive fractional shock				-0.003***			
				(0.000)			
WGI*categorical shock					-0.001	0.004	
					(0.003)	(0.003)	
WGI*positive categorical shock						-0.012**	
						(0.005)	
WGI* abs.categorical shock							-0.003
							(0.004)
adj.R-squared	0.410	0.410	0.410	0.412	0.410	0.410	0.412
Observations	24376	24376	24378	24378	24388	24388	24388

Notes: Standard errors are computed by Hsiang (2010)'s GMM method and reported in parentheses. All regressions include control variables, country fixed effects, and country specific trend.
* p<0.1, ** p<0.05, *** p<0.01.

Table 15 Governance, Rainfall Shock, and Conflict Onset Using Hsiang (2010)'s GMM Method

	(1) Conflict	(2) Conflict	(3) Conflict	(4) Conflict	(5) Conflict	(6) Conflict	(7) Conflict
rainfall growth	0.001	0.001					
	(0.003)	(0.003)					
fractional shock			-0.001	-0.001			
			(0.001)	(0.001)			
categorical shock					-0.017	-0.017	
					(0.012)	(0.012)	
abs. categorical shock							0.060***
							(0.018)
WGI	-0.017***	-0.016***	-0.016***	-0.014***	-0.016***	-0.015***	-0.015***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
WGI*rainfall growth	0.001	0.458**					
	(0.001)	(0.213)					
WGI*positive rainfall growth		-0.457**					
		(0.213)					
WGI* fractional shock			0.000	0.001**			
			(0.000)	(0.000)			
WGI*positive fractional shock				-0.001***			
				(0.000)			
WGI*categorical shock					0.002	0.004	
					(0.002)	(0.003)	
WGI*positive categorical shock						-0.004	
						(0.004)	
WGI* abs.categorical shock							-0.001
							(0.003)
adj.R-squared	0.122	0.123	0.123	0.123	0.123	0.123	0.124
Observations	22634	22634	22636	22636	22646	22646	22646

Notes: Standard errors are computed by Hsiang (2010)'s GMM method and reported in parentheses. All regressions include control variables, country fixed effects, and country specific trend.
* p<0.1, ** p<0.05, *** p<0.01.